CONGRESS OF THE UNITED STATES OFFICE OF TECHNOLOGY ASSESSMENT

CONGRESSIONAL SUMMARY

TECHNOLOGY TRANSFER TO CHINA

J952-41

Office of Technology Assessment

Congressional Board of the 100th Congress

MORRIS K. UDALL, *Arizona, Chairman*

TED STEVENS, *Alaska, Vice Chairman*

Senate

ORRIN G. HATCH
Utah

CHARLES E. GRASSLEY
Iowa

EDWARD M. KENNEDY
Massachusetts

ERNEST F. HOLLINGS
South Carolina

CLAIBORNE PELL
Rhode Island

House

GEORGE E. BROWN, JR.
California

JOHN D. DINGELL
Michigan

CLARENCE E. MILLER
Ohio

DON SUNDQUIST
Tennessee

AMO HOUGHTON
New York

JOHN H. GIBBONS
(Nonvoting)

Advisory Council

WILLIAM J. PERRY, *Chairman*
H&Q Technology Partners

DAVID S. POTTER, *Vice Chairman*
General Motors Corp. (Ret.)

EARL BEISTLINE
Consultant

CHARLES A. BOWSHER
General Accounting Office

CLAIRE T. DEDRICK
California Land Commission

S. DAVID FREEMAN
Lower Colorado River Authority

MICHEL T. HALBOUTY
Michel T. Halbouty Energy Co.

CARL N. HODGES
University of Arizona

RACHEL McCULLOCH
University of Wisconsin

CHASE N. PETERSON
University of Utah

JOSEPH E. ROSS
Congressional Research Service

LEWIS THOMAS
Memorial Sloan-Kettering Cancer Center

Director

JOHN H. GIBBONS

The Technology Assessment Board approves the release of this report. The views expressed in this report are not necessarily those of the Board, OTA Advisory Council, or individual members thereof.

Cover design by John Bergling

Foreword

Momentous changes continue to occur in China. The high priorities now accorded economic modernization and improved global relationships present a sharp contrast to the years of the Cultural Revolution and earlier. Yet there is great uncertainty over China's future course. China may be a constructive trading and strategic partner, or it may choose a more divergent path. U.S. decisions on technology transfer will be an important determinant of which path is followed and the implications for the world.

This report responds to requests from the House Committee on Energy and Commerce and the Senate Committee on Banking, Housing and Urban Affairs for an assessment of the economic and strategic implications of technology transfer to the People's Republic of China and of Congressional actions that would affect it. In addition, the Senate Select Committee on Intelligence endorsed the study request.

The first phase of this study focused on energy. A Technical Memorandum, *Energy Technology Transfer to China*, was released in September 1985, and proved useful in the Congressional debate on the nuclear cooperation agreement.

This document analyzes the factors in China that affect technology transfer and will be affected by it. The experiences of U.S. and foreign companies in the China market are described. We discuss the evolution of China's economy, polity and foreign policy, and how different expectations suggest different policies for the U.S. Government.

In the course of this assessment, OTA drew on the experience of many organizations and individuals. We appreciate the assistance of the project's contractors who prepared much of the background analysis, the U.S. Government agencies and private companies who provided much valuable information, the Chinese institutions which facilitated the visits of our researchers, the project's advisory panel and workshop participants who provided guidance and review, and the many additional reviewers who helped ensure the accuracy and objectivity of this report.

JOHN H. GIBBONS
Director

International Security and Commerce Program Technology Transfer to China Advisory Panel

Robert Dernberger, *Chairman*
Director, Center for Chinese Studies
The University of Michigan

A. Doak Barnett
Professor, School for Advanced International Studies
The Johns Hopkins University

Gareth Chang
President, McDonnell Douglas China Inc.

Chauncey Chu
Vice President of Manufacturing
Wang Laboratories, Inc.

Bo Denysyk
Vice President, International Affairs
Global U.S.A., Inc.

Basil K. Fox
Bechtel China Inc.

Admiral Thomas Hayward, USN (ret.)
President, Hayward Associates

Richard Holton
Professor, School of Business Administration
University of California

Morton Kaplan
Professor, Department of Political Science
University of Chicago

Arthur A. Klauser
Senior Vice President
Mitsui & Co. (USA) Inc.

Stanley Lubman, Esq.
Heller, Ehrman, White & MacAuliffe

Charles Lucy
Director, International Operations
Corning Glass Works

Bruce Lusignan
Professor of Electrical Engineering
Stanford University

Leo A. Orleans
China Consultant
Library of Congress

Professor William Parrish
Director, Center for Far Eastern Studies
University of Chicago

Vaclav Smil
Professor of Geography
University of Manitoba

Roger Sullivan
President
National Council for US China Trade

NOTE: OTA appreciates and is grateful for the valuable assistance and thoughtful critiques provided by the advisory panel members. The panel does not, however, necessarily approve, disapprove, or endorse this report. OTA assumes full responsibility for the report and the accuracy of its contents.

OTA Project Staff

Lionel S. Johns, *Assistant Director, OTA*
Energy, Materials, and International Security Division

Peter Sharfman, *International Security and Commerce*
Program Manager

Alan T. Crane, *Project Director*

Eric O. Basques:
U.S. Commercial Experiences, Military Technology

Martha Caldwell Harris:
U.S. Policy, Multinational and Strategic Issues

Richard Peter Suttmeier:
China's Context, Trends, and Foreign Policy

Contributors

Craig Allen Matthew J. Bryza Joanne Sedor

Alan Shaw Franklin Zweig

Administrative Staff

Jannie Coles Cecile Parker Jackie Robinson

In Memorium

Dottie Richroath

Contractors

Thomas Fingar
William A. Fischer
Paul Folta
Thomas W. Robinson
Denis Simon
Kathryn Van Wyk
China Business Development Group
Global Associates, Ltd.
Midwest China Center
Rock Creek Research, Inc.
Science Applications International Corp.

Photo credit: Eric Basques

Bronze Crane in the Forbidden City in Beijing.
The crane is a legendary symbol of long life.

Technology Transfer to China

A billion people! If they each buy just one . . .
If we give them technology, they'll be just like Japan . . .
In a country that can launch satellites, why is the plumbing so bad . . .
All they want is technology, and they expect miracles from it . . .
It's completely different now. It's hardly even Marxist . . .
So where are all those Red Guards now? Aren't they just waiting . . .
If we don't sell it to them, France or Japan will . . .
They'll pin down the Russians on the Eastern front . . .
How do we know they won't use it against Taiwan—or us . . .
There's a lot we can learn, too . . .

China evokes countless, often contradictory, expectations and impressions. What is clear is that China will become increasingly important to the United States over the next several decades. Its impressive economic growth in recent years, if continued, will propel it into the ranks of the newly industrialized economies of Asia—Taiwan, South Korea, Hong Kong, and Singapore—but eventually on a much larger scale. International trading patterns are likely to change dramatically as China increases both imports and exports. China will also acquire increasing political influence in world affairs as its economic, technological, and military strengths grow. U.S. interests in Asia will be profoundly affected by China's international role, including its relations with the Soviet Union, Taiwan, and other neighbors.

As important as these developments are, the U.S. ability to influence them is limited. China's economic growth is much more dependent on internal Chinese factors than on any U.S. actions, and China will play its international role on the basis of its own perceived best interests. What the United States can do is reinforce China's constructive choices and trends, and protect itself against the risk that Sino-American interests will again diverge.

One of the most important influences that the United States has is technology transfer. China recognizes the need to acquire new technology and new capabilities in its efforts to modernize and expand its economy. This need was one of the main reasons for ending its self-imposed isolation and for opening itself to the West in the 1970s. The United States benefits insofar as China is a strategic asset, if not an ally, in the global competition with the Soviet Union. Technology transfer helps build these ties and increases China's strength vis-à-vis the

Soviet Union. It also can lead to important commercial ties and to the export of American products. In addition, China is still a very poor country, and technology transfer can be an important element in humanitarian efforts to help a billion people move out of poverty.

U.S. policy toward China for the past 10 years has been predicated on the assumption that closer relations are generally beneficial but that caution must be exercised in the transfer of advanced, sensitive technology. This policy has had some success: China has played a more constructive international role, and many areas of common interest (reportedly including sensitive intelligence gathering) have been found. Trade has also become significant. With so much gained, some ask whether further steps are warranted—in particular, whether the United States should make greater efforts to help China modernize through technology transfer.

However, the reasons for caution have not been eliminated, and some observers feel that U.S. policy has gone too far: that China is a potential adversary, with an alien ideology and an unstable, unpredictable political system. Others see China as a newly industrializing country that is rapidly upgrading its production technology and agressively seeking international markets, becoming another, potentially much more powerful, Japan or Korea. Both views suggest great caution with respect to technology transfer.

It is the intent of this assessment to put these views into perspective and to contribute to a reexamination of U.S. policy toward China. The assessment evaluates the economic, political, and strategic implications of technology transfer to China in the context of China's capabilities and evolution. It reviews the U.S. commercial and governmental role in technology transfer, and the policies and practices of other countries. It asks whether the application of U.S. policy has been consistent with the overall guidelines, and analyzes policy options for Congress in the areas of export control, trade promotion, and military cooperation.

As used in this assessment, *technology transfer* is a process whereby a government, company, or institution provides the information necessary for China to improve its capability to design or produce goods or services. It may or may not involve the sale of equipment, but it

almost always involves exchanges of information between people. Technology transfer may involve the transfer of sophisticated equipment, training in its use and maintenance, and information on design or manufacture. Indirectly, it may include the teaching of technology and management in universities. Commercial technology transfer can be accomplished through sales of equipment or expertise, licensing agreements, direct sales of information, or investments in China. The U.S. Government transfers technology by granting access to information (e.g., the U.S. National Technical Information Service) and through agency-to-agency agreements.

Technology transfer can provide some of the keys China needs to meet its modernization goals. Modernization, in turn, will enhance China's position as an exporter and will eventually enhance China's military strength. The positive and negative implications for the United States can be estimated only imperfectly. The following sections summarize the critical factors.

CHINA'S NEED FOR TECHNOLOGY

China has considerable technological capability already, especially compared with that of other developing countries, but progress has been very uneven. Military industries in particular have been favored with priorities for investments and personnel. Some of these industries have developed "pockets of excellence" that can compete in world markets. For example, China has built and launched its own experimental communication satellites and has offered to launch foreign satellites. The military sector has now been ordered to help the civilian sector, especially since many military factories are underutilized because of the recent lowering of defense budgets. **If this expertise can be used effectively, it may have a substantial impact on civilian production and exports.**

Much of China's civilian technology is out-of-date, if not obsolete. The Seventh Five-Year Plan (1986-90) has set the acquisition of technology as a high priority, especially in the fields of transportation,

electronics and computers, telecommunications, and energy. The plan calls for importing much of this technology. One of the "Four Modernizations"--the policy program for development—was to raise the level of science and technology. The others—agriculture, industry, and defense—also to a large degree depend on improvements in technology. Some of these improvements could be accomplished by the purchase of modern equipment without technology transfer, but China has limited funds for imports. China could develop some technologies independently, but in general this would be much slower and less efficient than acquiring them from abroad.

China has ambitious goals, including a quadrupling of the 1980 industrial and agricultural output by year 2000. Progress so far has been above that rate (about 7 percent), primarily because a loosening of controls has freed a latent strength in the economy. New technology has made only a minor contribution but will be of increasing importance in the future. Goals for economic growth will not be met without improved technology to modernize industry and to alleviate constraints in energy, transportation, and communications.

Technology transfer can foster not only an increase in production, but also an increase in the quality of products. Modern industrial equipment can easily surpass the quality levels of the antiquated equipment typical of Chinese factories. Exposure to modern management practices, which technology transfer often entails, broadens the Chinese manager's concepts of what can be accomplished and how. Coupled with these new tools has been the realization of the need for quality in products if China is to compete well enough in world markets to earn the foreign exchange to continue buying technology.

However, China's modernization does not yet appear to have reached the point where improvements in one sector lead to improvements in others. There have, of course, been many examples of successful assimilation of specific technology transfers, but there have also been many cases of failure or incomplete success. For instance, computers and other modern equipment sometimes remain unused because of a lack of expertise or an adequate supply of a necessary input, such as electricity.

The question is not whether China is capable of modernization, but whether it is willing to make enough of the changes required for continued, rapid modernization. Like other centrally planned economies, China developed a pattern of decisionmaking that discourages efficiency and innovation, and gives the management of a productive enterprise few incentives to improve. The economic reforms that have been initiated since the Cultural Revolution have been directed at providing workers and management with incentives to increase output and quality and to improve economic decisionmaking. Measures taken include increasing the autonomy of enterprises, allowing them to retain and reinvest earnings, freeing up some markets, loosening price controls, and reducing the role of the Chinese Communist Party. Re-

forms have been successful in agriculture but less so in industry. Delays in price reform and opposition by those fearing loss of their power have slowed improvements in efficiency.

China's "Open Door" policy is closely related to economic reforms and is intended to facilitate technology transfer and trade. Under this policy, economic zones and coastal cities have been opened to foreign investment, and joint ventures and cooperative manufacturing have been encouraged.

To date, however, the results have been somewhat disappointing. Investments have been lower than expected, and many problems have been encountered, including high costs, shortages of skilled workers and supplies, and unfamiliarity with quality and scheduling requirements. Moreover, most enterprises are risk-averse, and the incentives for new capabilities may be weak if other constraints (e.g., energy or materials) limit production in any case. **Delays and uncertainties caused by the intricacies of Chinese bureaucracy have been particularly frustrating for outsiders trying to do business.** Although the Ministry of Economic Relations and Trade (MOFERT) was established to facilitate trade, the process is still cumbersome and full of pitfalls. If new technology is sought, approval may be needed from both the local authorities and several agencies of the central government, depending on the enterprise, the priority of the technology, and the cost.

The shortage of foreign exchange has become critical over the past year. Unlike many developing countries, China has refused to go heavily into debt, and it has had many competing requirements for its declining foreign exchange reserves. Decisions on which technologies to import are now frequently biased by considerations of how much foreign exchange can be earned rather than by how much the Chinese economy would benefit. Petroleum technologies have been particularly favored because petroleum is one of the most important exports, even though infrastructure (e.g., electric power, transportation, communications) inadequacies have been much more of a constraint on the economy.

Despite many problems, China's economy is growing very rapidly and that is likely to continue. There is also evidence that the technology transfer process is improving, and that modernization will benefit considerably.

THE U.S. ROLE IN TECHNOLOGY TRANSFER

Most technology transfer from the United States is from private companies. Although most U.S. firms approach the China market with the intent to sell products, many find they must include technology transfer if they wish to gain access to the China market. The variety of experiences are illustrated by the following examples:

- General Electric won two large orders for locomotives in part by a willingness to transfer the technology of materials and manu-

Photo credit: General Electric

A General Electric Co. locomotive pulls a train near the Great Wall. GE's locomotive contracts have included technology transfer in the form of training and information.

facture. G.E. is not setting up any manufacturing facilities in China, though an important part of the contract stipulated that China would produce several of the parts for the locomotives. The first contract took several years to negotiate. The second needed only a few months, largely because trust had developed among the participants. G.E. was also flexible in tailoring the locomotive design to Chinese requirements.

- American Motors established a joint venture with the Beijing Automotive Works to produce AMC's Cherokee model. Initial production has used parts sent from the United States. The intent was to increase the local content as rapidly as possible, but China has been unable to produce parts and supplies in the quantity and quality required. As a result, costs are high and export of the Cherokees has been impractical. China's foreign exchange crisis interfered with the purchase of U.S. parts, leading to a shutdown of the plant for 2 months, though a compromise has allowed restart.
- McDonnell Douglas has started coproduction of 25 MD-82 twinjet transports with the Shanghai Aviation Industrial Corp., following a sale of 5 to China. The planes are being produced partially under the direction of Americans, with the first plane expected

to fly in 1987. Training will also be provided for the Chinese in the United States. The planes are to be certified for airworthiness by the U.S. Federal Aviation Administration, which provides an explicit standard for quality control.

- There have been no commercial satellite telecommunication sales despite two sets of proposals by U.S. and European companies. The Chinese received considerable technology transfer for free as a result of these proposals, but that probably was not their intent. Rather, China's conflicting priorities and bureaucratic power struggles, combined with the shortage of foreign exchange, have delayed a decision. China has launched two geosynchronous communication satellites of its own design, but both were relatively unsophisticated. It is unlikely that China's own products will be competitive for several decades, even with imported technology. The parallel effort on rockets is much more competitive, especially since the U.S. and European programs are temporarily inoperative because of accidents.
- IBM has been very successful in selling computers to China, but has not yet initiated any manufacturing. Technology transfer has been largely limited to training in the use of computers. IBM may be in a unique situation to resist pressures for investment in China because of its dominant role in the international computer industry.
- Wang Laboratories is preparing at least one joint venture for the assembly and eventual manufacture of microcomputers. Included would be engineering, managerial and manufacturing expertise, software diagnostics, and after-sales techniques. This effort would complement Wang's sales to China and its manufacturing in other countries. However, Wang is concerned about China's lack of experience with large-scale production and the difficulty of maintaining quality control.

One hallmark of these cases is the lengthy negotiations. Wang started in 1980, and negotiations are only now coming to a conclusion. The McDonnell Douglas agreement took 10 years. The satellite proposals started in the late 1970s, with no commercial results yet.

China's shortage of foreign exchange has become a critical problem in cases such as AMC's joint venture. The import of supplies and the repatriation of profits are difficult. Recent Chinese regulations require foreign ventures to export or supply advanced technology in return for access to China's market. In many cases, however, the quality of the goods produced is not up to international standards, which greatly limits exports.

In addition, taxes and unexpected expenses have made China one of the most expensive places in the world in which to do business. A company usually cannot hire its own employees; they are supplied

by the state at a cost far higher than their actual salaries, and they cannot easily be replaced if they are incompetent or are transferred by the state. One of the main advantages of manufacturing in China—low-cost labor—is thus lost. Chinese managers also tend to be very cautious and frequently seem to lack a spirit of innovation.

High costs and bureaucratic rigidities are particularly difficult for small companies to manage. Few can afford to have a representative in China or continue negotiations for extended periods. Small companies are also particularly disadvantaged by complex export controls. However, some small companies have established profitable niches, particularly in the sale of specialized equipment.

Overall, businesses report mixed results in China. Some have lost money on early ventures, in the hope of building a profitable, long-term relationship, only to find China turning to competitors or dropping those imports altogether. **The investment climate is particularly poor**. The rate of foreign investment dropped by over 20 percent in 1986. China's leaders have recognized that foreign companies are being deterred by many regulations and costs over which the Chinese Government has control, as well as by more intractable deficiencies in skilled manpower, infrastructure, and resources. Significant steps have been taken to improve the atmosphere for foreign business (e.g., preferential tax treatment), but it remains to be seen whether these will be adequate.

It should be noted that some U.S. companies are doing quite well in China, particularly those that are not involved in joint ventures or other manufacturing investments. Two-way trade is over $8 billion and is still rising. Some companies recognize that it takes a long time to get established but are convinced that eventually the Chinese market will justify their patience. Others are waiting for other markets to improve, and anything sold to China will help bridge a gap, even if at little or no profit.

U.S. Government agencies are also involved in technology transfer as part of an overall effort to cooperate with China and improve relations. A broad agreement on science and technology cooperation was signed in 1979, and 25 protocols implementing the agreement in specific areas such as telecommunications, agriculture, space, environmental protection, transportation, and student/scholar exchange have been signed. Three more are pending. These contacts have facilitated commercial transactions and improved political contacts.

The presence of 17,000 Chinese students and scholars (half of those sent abroad) in American universities has been one of the most effective forms of technology transfer. Most students are in science or engineering courses. It appears that most students leave with friendly personal ties as well as an education, but it is not yet clear whether this will lead to commercial or political benefits for the United States.

The United States has many advantages in competing for the Chinese market (e.g., a reputation in China for advanced technology, con-

nections through many Chinese-Americans, the popularity of the English language in China) but other countries seem to be doing relatively better in trade. Japan exports twice as much to China, and the nations of Western Europe collectively exceed the U.S. level. There are several reasons for this: American companies historically have been less concerned with exports, which have been very difficult during the last few years because of the high dollar. However, government trade policy is also a direct influence. **U.S. export controls are time-consuming and laborious compared with those of other countries, and appear to be applied more rigidly**. Moreover, Japan and West Germany have extensive foreign aid programs in China that lead to considerable trade. Japan, France, Italy, and others provide extensive official financing for exports. As discussed below, the United States does not necessarily have to emulate these tactics, but changes could be considered to improve the competitiveness of American companies.

ECONOMIC AND POLITICAL IMPLICATIONS

Technology transfer will have profound long-term impacts on China's economic and political future. Some sectors such as consumer electronics will benefit considerably because the industry has a head start or because the technology is more easily assimilated. Past experiences suggest that others will find foreign technology to have little effect because the industry is unprepared. **Dissemination of the management concepts of quality, efficiency, and timeliness may be the most important result of technology transfer**. Improvement in the quality of Chinese products (necessary for them to compete in international markets) may be the first general impact of technology transfer to be visible.

It appears quite probable that China's economic growth will remain high (above 5 percent and possibly over 7 percent). The goal of quadrupling the 1980 output by year 2000 should be attainable, though several factors could interfere. Foreign exchange limitations, energy constraints, and political instability could all hold the growth rate down.

China's exports should also rise rapidly over the next 15 years, but the competition with American products will not be great. The newly industrializing economies, including Korea, Taiwan, Mexico, and Brazil are more likely to feel the competition. Direct competition with either industrialized countries or less developed countries is less likely because the product mix will be different. One exception may be American agricultural exports to Asia, which could be hurt by rising Chinese surpluses. On the whole, however, China's increased role in the international economy should be beneficial for the United States.

Several factors may slow China's export growth: rising protectionism in the developed countries may preclude growth in sectors, such as textiles, where China is strong. Diminishing foreign exchange reserves

72-250 O - 87 - 2

Photo credit: McDonnell Douglas Corp.

Construction of an MD-82 twin jet transport at the Shanghai Aviation Industrial Corp., under a coproduction agreement with McDonnell Douglas Corp. The 25 planes will be certified by the U.S. Federal Aviation Administration.

could limit China's ability to invest in new productive capacity. If the quality of China's products doesn't improve sufficiently, there will be limited markets for them in the West, and China may have to turn to the Soviet bloc for trade and credit, a trend that is already appearing.

There is a strong relationship among modernization, economic reforms, political changes, and technology transfer. As long as modernization is a prime goal (as it has been for the last 10 years), most economic reforms made to date will be retained. Modernization depends on technology transfer to achieve more efficient production, and further economic reforms will be needed to assimilate technology. However, the economic reforms are straining the political system, as evidenced by reactions to recent public demonstrations. If political reforms do not reinforce economic reforms, modernization is likely to be slow.

Some of the more difficult economic reforms have yet to be implemented. Price decontrol is essential for rational economic decisionmaking, but it strikes at the heart of the concept of the planned economy.

Mobility of labor would increase productivity but would bring unaccustomed social dislocations. Recent developments suggest that there is a strong resistance to reforms such as eliminating the control of Communist Party cadres over factory operations. If China insists on making ideology preeminent, it is unlikely to greatly improve its economic efficiency.

The leadership succession to Deng Xiaoping is one of the most crucial questions. Virtually all of China's leaders support economic reform, but there are major differences of opinion over how fast and far it should proceed. Promoting technology transfer benefits the United States by strengthening the hand of reform-minded leaders who have favored opening up to the West, largely to obtain technology.

If China's modernization program turns out to be even a partial failure, there are likely to be negative implications for the United States. A society disappointed and frustrated from unmet expectations of economic improvement would be more susceptible to political extremism, which could easily have ramifications for Taiwan and Korea. China would also be a less valuable trading partner for the West and could move closer to the Soviet bloc which presents fewer demands for hard currency and quality products.

However, successful reforms will create their own problems. Rising expectations of the population and critical environmental problems will make enormous demands on the leadership. Economic and political changes are creating an environment that will encourage a pluralism of ideas and a liberalization that is incompatible with traditional Communist Party control. It remains to be seen whether the party can accommodate itself to these changes and define a new social role, or whether it will attempt to slow modernization to preserve its control. The present problems of the reform movement indicate that the party conservatives still have considerable power, but China's political evolution is likely to exhibit many unpredictable shifts.

STRATEGIC IMPLICATIONS

Technology transfer will assist China's military. The important questions are how much it will help and how much that matters to the United States or its allies. The first question involves China's military needs and internal capabilities, the second involves China's foreign policy.

At present, China's military is large but unsophisticated technologically. It has a great many tanks and planes, some missiles, nuclear warheads, and ships, and even a few nuclear submarines, but all are outdated and much less effective than U.S. or Soviet equivalents. China is not a major power even regionally, as demonstrated by its ineffectual excursion into Vietnam in 1979. China's military capability is improving, especially in the strategic forces needed to deter a Soviet attack and in nontechnical ways such as command structure and professionalism, but the process will be gradual.

China's military can benefit from foreign technology in three ways: it can buy military technology directly, obtain civilian technology that has military applications, or develop its own modern weapons systems as its economy as a whole modernizes.

The United States and other nations have offered to sell military equipment to China, including the avionics package for the F-8 fighter, but there have been few contracts because China apparently cannot afford to buy many weapons systems. **Acquiring modern weapons would be the fastest way to a modernized military, but China does not feel the need to be pressing enough to sacrifice its economic priorities.** Instead, it prefers to import technology rather than equipment, a rationale particularly compelling for the military, which often needs very large quantities of each piece of equipment.

The transfer of dual-use technologies has increased rapidly. While it is reasonable to assume that China's military has access to such technology if it demands it, that does not mean that the military will be able to use it effectively. Until recently, civilian and military enterprises were kept separate, with the military being given priority on resources and talent. Military factories were significantly more sophisticated than civilian ones. This has changed over the past few years. Civilian factories have enjoyed much more technology transfer and appear to be modernizing faster. Both have exhibited considerable difficulty in assimilating new technology. For instance, the United Kingdom transferred the Spey jet fighter engine technology, but the military factory never was able to manufacture it successfully. Examples of successful reverse-engineering are very few. Chinese military factories produce large quantities of unsophisticated weapons that sell well in the Third World, but their production of sophisticated systems is very limited.

Modern military systems are complicated and demanding. They must be designed by teams of talented and experienced engineers and scientists representing a variety of disciplines. Their manufacture calls for additional expertise and the availability of precision production equipment and high-quality supplies. **China's difficulty in assimilating advanced technologies suggests that more could be transferred without incurring much risk that China will use them to produce sophisticated weapons systems, but this risk will grow over the years as China's technological capability improves.**

For instance, table 1 shows the major components and technologies involved in anti-submarine warfare (ASW), one of the key mission areas which would significantly enhance China's overall military capability. Critical ASW technologies should not be transferred unless there is an explicit political decision that this would be in the U.S. national interest. Those technologies that are unique to ASW are clearly critical. Others are so readily available for commercial uses that no purpose would be served in trying to contain them. The difficulty comes with the intermediate, dual-use technologies, such as spectrum analyzers, the electronic instruments used to identify the source of noise by analyzing the acoustic patterns.

Table 1.—Anti-Submarine Warfare Technology

Anti-submarine warfare (ASW) is the detection, identification, and destruction or disabling of an enemy submarine. ASW can be conducted from any suitable "platform" from the air, sea surface, or from another submarine. The basic functions needed to successfully conduct the ASW mission are the same for each platform:

1. **Detection**: by either acoustic or nonacoustic methods.
2. **Classification**: determination of the type of target.
3. **Localization**: target motion analysis and contact management.
4. **Approach to the Target**: closing in on the submarine to within range of one's own ship or aircraft weapons.
5. **Weapon Deployment (Launch)**: actual attack.
6. **Evasion and Reattack**: performed if necessary.
7. **Related Functions**: tactics such as mine avoidance, mine deployment, and surveillance performed as necessary.

Although the basic required ASW functions listed above are always the same, the complexity and difficulty of each of these elements varies from case to case and from platform to platform.

There is no one ASW technology. These functions require the implementation of many different technologies, and capabilities are required across a broad spectrum of engineering and science. Some technologies are critical in the sense that if their performance is substandard, the whole ASW system is significantly affected. Each increased level of sophistication will have a higher level of success in ASW, but there are many different levels that can be successful. Following are the critical technologies, grouped by commercial availability.

a. *Critical technologies not commercially available (easily controlled):*
   - Propulsion design
   - Low-noise machinery design
   - Sonar dome
   - Transducer design
   - Classification techniques/algorithms
   - Acoustic correlation algorithms
   - Contact motion analysis
   - Tracker design algorithms
   - Passive ranging techniques
   - Weapon guidance
   - High-density power-pack design
   - Small-size high-power train design
   - Exotic fuel design
   - Power engineering
   - Multipath processing techniques

b. *Critical technologies with less sophisticated versions available commercially (control is complex):*
   - Low-speed turbines
   - Bearing design
   - Baffle design
   - Beamformer techniques
   - Local area network design
   - Spectrum analyzer design
   - Microelectronic design
   - Beamformer design
   - High-speed graphic techniques
   - Color/bit plane graphics
   - Shape charge techniques
   - Fusing design
   - Magnetic anomaly detection

c. *Critical technologies readily available commercially (controls futile):*
   - Corrosion resistance
   - Ceramic design
   - Elastomer technology
   - Machinery isolation
   - Spectral analysis algorithms
   - Acoustic performance prediction techniques
   - Environmental sampling techniques
   - High-speed math processor design
   - Minicomputer design
   - High-explosive technology

SOURCE: Adapted from "Assessment of ASW Technology Transfer to the People's Republic of China," contractor report prepared for OTA by Global Associates, Ltd., Alexandria, VA, December 1986.

Spectrum analyzers are sold frequently to China, including sophisticated models that would be useful in ASW (though they would not play a prime role in U.S. ASW). However, this technology would be extremely difficult to reverse engineer. Moderate relaxation of controls over exports of spectrum analyzers would give China access to more equipment to upgrade its ASW, but would not in itself seriously

effect U.S. security interests. However, any such decision has to be considered in the context of other technologies that are being made more available, China's growing technological capabilities, its political intentions and the impact on U.S. allies.

It is likely that military needs are considered when foreign technology is sought. The Chinese National Defense Science, Technology, and Industry Commission reviews requests to determine priorities, but no pattern of technology targeting is apparent. The civilian technology that China seeks has justifiable commercial uses. Considering China's great need for most technologies, the Soviet practice of targeting militarily significant technologies would seem to be irrelevent. There is little evidence that imported dual-use technology has been a significant factor in China's military modernization.

If China is to become a major power, it will be through developing its own capabilities throughout the economy. Thus, in the long term, technology transfer will have a great military effect if it spurs innovation, modernized thinking, research and development, and economic growth generally. However, China will not have the economic depth to become a superpower for several decades, especially considering the progress the United States and the Soviet Union will also be making.

U.S. policy includes the principle of military cooperation, but within certain limits. Many dual-use technologies have been transferred because any gains to Chinese defensive power are likely to be of greater Soviet than U.S. concern. Military cooperation has been seen as a natural part of the growing relationship, but concrete steps toward cooperation have been tentative. U.S. arms sales to China, while increasing, remain well below the level of sales elsewhere in Asia, such as to South Korea and Taiwan.

At worst, the current policy of technology transfer to China entails only moderate direct risk to the United States. China will not have the strategic strength for serious threats for several decades. While China has a few intercontinental ballistic missiles capable of reaching the United States, it also has compelling reasons not to launch them. However, other U.S. interests could be threatened more easily. **In particular, as a regional power, China would be capable of putting great pressure on U.S. allies in East Asia.**

Asia has been a region of relative stability and peace since the end of the Vietnam war, with the exception of the Kampuchean problem. There are, however, tensions and several potential flashpoints, specifically Korea and Taiwan. Military outbreaks could become of global significance, especially considering the U.S. and Soviet interests in the area. **The large-scale Soviet military buildup and political initiatives are the greatest concerns to the United States. China shares this perception, which has become the basis for de facto military cooperation, though China is very unlikely to jeopardize its status as self-appointed Third World spokesman by an overt alignment.**

Some of China's neighbors, however, may see China as a potential threat. Asian attitudes toward China are complex and vary from coun-

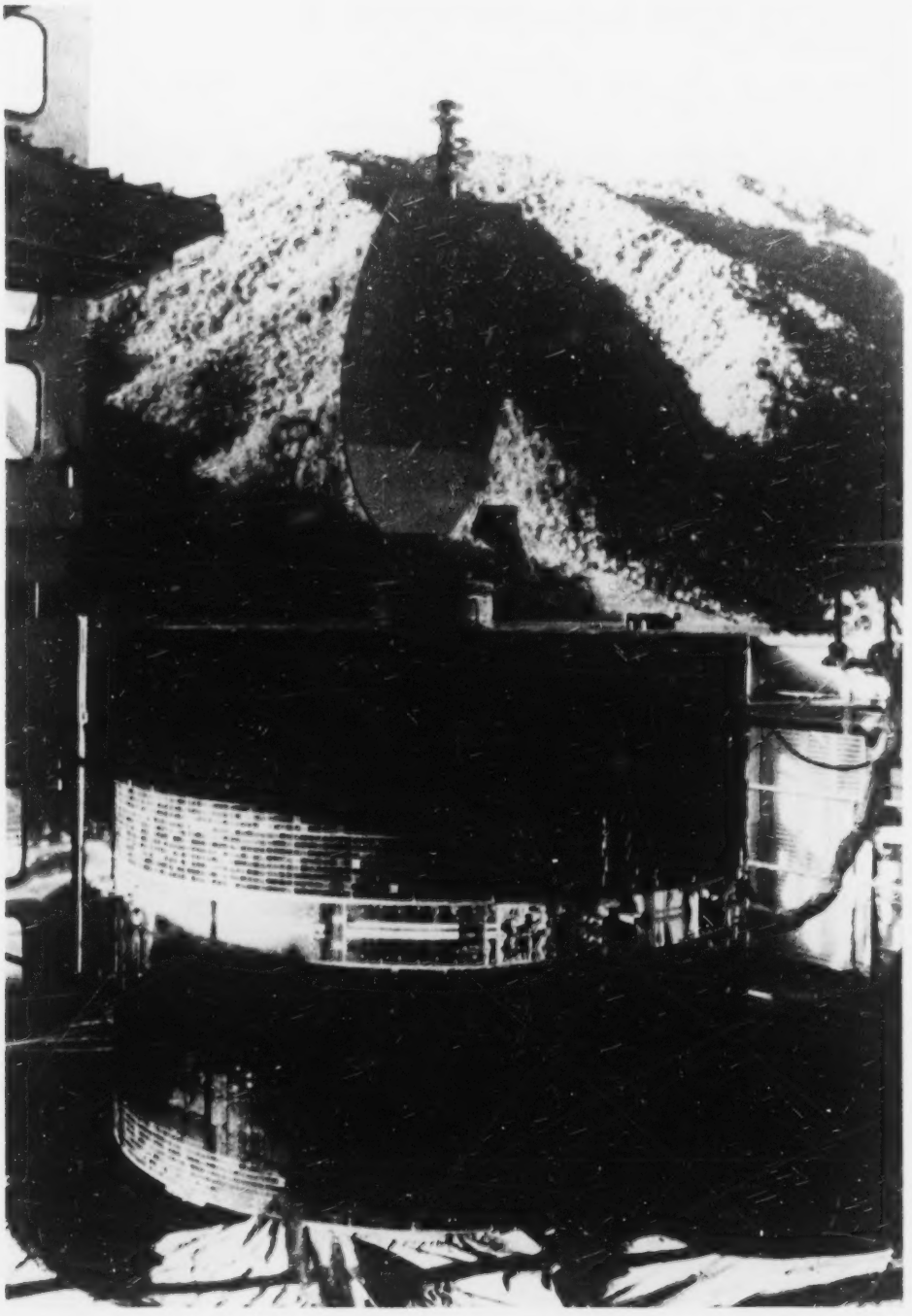


Photo credit: Xinhua News Agency

A Chinese-developed communications satellite, which was launched into geosynchronous orbit in February 1986 on the Long March 3 rocket. China's satellite technology is progressing rapidly, but it is still well behind that of the United States or Europe.

try to country. All share China's desire to see a Vietnamese withdrawal from Kampuchea and are relieved to see China focusing on economic growth rather than exporting revolution. However, there are misgivings about the effects of U.S. technology transfer on China's economic competitiveness and concern about China's growing influence. Many

Asian countries have large Chinese populations, compounding the uneasiness. Such feelings may be inevitable, considering China's size, but special sensitivity by the United States may help minimize future problems. For instance, consultations with these countries on U.S. relations with China may provide reassurances of U.S. intentions.

U.S. POLICY CHOICES

U.S. policy currently supports the transfer of technology to China, but within certain limits set by national security considerations. The fundamental rationale for this policy, supported by four U.S. administrations, is that assisting China in its modernization will serve U.S. interests. This general framework represents a compromise between optimism and caution, and permits a flexible approach to specific policy choices. For example, advanced dual-use technologies and arms can be exported on a case-by-case basis, depending on the nature of the technology, the Chinese recipient, the conditions of the sale, and other factors.

The flexible approach has permitted the relaxation of controls as relations have improved and has brought significant benefits to the United States. However, case-by-case export controls are complex to administer (delays in export licensing are often the result) and can yield inconsistent decisions.

U.S. policy also includes some promotional programs to foster exports of nonsensitive equipment and technologies, but these programs are much less extensive than those of Japan, France, and other countries. There is no U.S. aid program and government financing of exports is quite limited relative to other countries.

There is a broad consensus that overall policy is on the right track, but changes in emphasis could be considered to improve the benefits for the United States. One alternative theme would emphasize a more activist strategy of technological cooperation: explicitly using technology transfer to improve relations and trade. Another possibility would be to make better use of technology transfer as a bargaining chip in U.S.-China relations. A third would be to emphasize the multilateral aspects of export control and trade with China.

It would of course be possible to pull back and further restrict technology transfer. However, in the current climate of improved U.S.-China relations, such an approach would appear to be counterproductive. It would alienate China without denying it access to advanced technology, given the availability from many other suppliers. If the worst fears are realized, and China does revert to hostility, the present system can adapt to the change.

Regardless of whether or not a more explicit strategy is developed, a number of specific issues will be addressed by Congress. Most attention has been focused on export controls. For advanced exports with military significance, the United States maintains a system of

extensive reviews to ensure that U.S. national security is preserved. The Department of Commerce (DOC) is the lead agency, but the Departments of State and Defense also participate. Multilateral review through COCOM[1] is also required on many such exports.

U.S. industry has been critical of China export controls, protesting lengthy reviews and contracts lost to firms from other countries as a result of more stringent U.S. controls.[2] OTA's research confirmed that other countries are generally able to reach a decision on even sophisticated dual-use exports in a few weeks, while the United States frequently requires months or even years. In addition, only the United States unilaterally imposes controls on items not on the list of COCOM controlled items, and requires that exports to allied countries, if reexported to third countries, be again subject to the original licensing. The latter requirement has also caused considerable discord between the United States and other COCOM members.

It is difficult to quantify sales lost due to export controls, because so many factors affect the competitiveness of U.S. firms in the China market. The green zone (items likely to be approved for export) has been expanded to cover items in 30 categories on the Commodity Control List. **Today, U.S. controls on exports to China affect primarily a few key advanced technology sectors such as computers, telecommunications, precision instruments, and advanced manufacturing equipment—areas where the United States might otherwise have a significant competitive advantage.** In 1986, computing equipment alone made up almost 80 percent of the value of export licenses approved. Thus, while U.S. controls are not the critical factor determining the overall volume of trade with China, delays can considerably affect the advanced technology exports that China wants.

In recent months there have been signs of improved efficiency in license review. Average processing time for China cases has declined to 57 days in April 1987. However, the processing time for referred China cases (those reviewed by agencies in addition to DOC) continues to take almost 6 months on average. OTA found that 134 China cases valued at $145 million had been in the system for more than 1 year as of January 1987. Figures 1 and 2 show the trends in processing time for referred and nonreferred cases. China cases comprise about one-third of the total for all countries pending over statutory limits in 1986.[3]

There are several steps the U.S. Government could take to clarify export control guidelines and improve licensing administration. The process of license review could be made more consistent by expanded

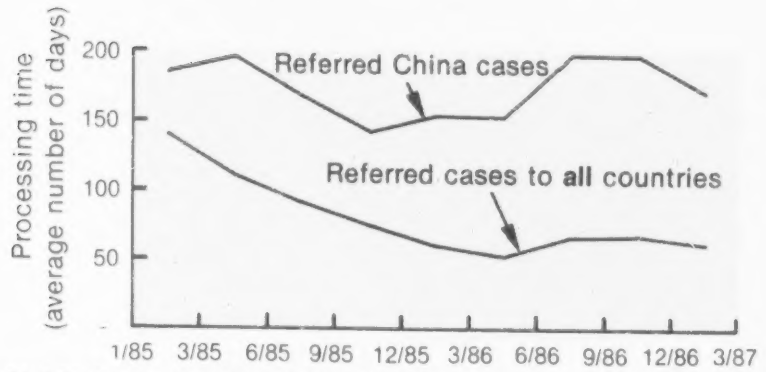
---

[1]The Coordinating Committee for Multilateral Export Controls, an informal organization of the NATO countries plus Japan, which seeks to harmonize export controls.

[2]OTA's analysis focuses on controls on exports to China. A recent study by the National Academy of Sciences examines the impact of U.S. national security export controls as they affect global competition: *Balancing The National Interest: U.S. National Security Export Controls and Global Economic Competition* (Washington, DC: National Academy Press, 1987).

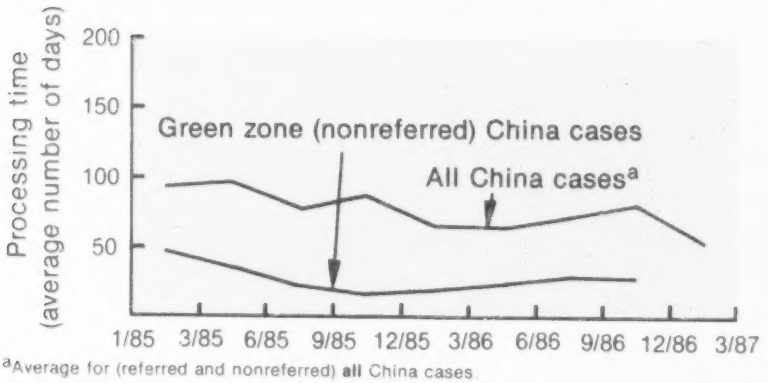
[3]Congress has established deadlines for license processing in the Export Administration Act.

Figure 1.—Processing Time for Referred (Closed Out) Cases



SOURCE: Office of Technology Assessment, 1987.

Figure 2.—Average Processing Times: China Nonreferred and All China Cases



[a]Average for (referred and nonreferred) **all** China cases.

SOURCE: Office of Technology Assessment, 1987.

use of computerized information on precedent-setting cases. **Additional technical analysis could be applied to develop U.S. positions for an expanded green zone and to develop sectoral approaches for technology transfer to China.** At a broader level, improved mechanisms for resolving disputes among executive branch agencies would reduce processing times for referred cases.

If policymakers wish to relax controls, the key question is whether exports of technologies that are now controlled might endanger U.S. or allied security. **For the near term, there are few dual-use technologies that would make a big difference in China's military capability if transferred.** The discussion of ASW and spectrum analyzers above illustrate how many technologies must be mastered and coordinated to produce usable, sophisticated military systems.

Supercomputers are one of the exceptions. Decisions about such a transfer must take into account a broad array of factors. A supercomputer is useful in a number of defense applications, such as satellite imaging, acoustical intelligence, and nuclear weapons design. China has indigenously developed a supercomputer. It appears to be significantly less capable than the Cray-2 or Cyber 205, but it indicates that China has the expertise to make use of advanced computer technology. However, if an American supercomputer were exported, the Chinese would also need sophisticated software. Programs to simulate weapons design, for example, would not be transferred. Chinese scientists could produce usable software, but it would be years before they produce such sophisticated software as that used in advanced U.S. weapons design. An American (or Japanese) supercomputer would eventually be a significant asset for China for improving its own technology and for solving problems, say, in missile accuracy. If China is allowed to buy a supercomputer (perhaps for weather forecasting as authorized for India), conditions could be applied, such as limiting access to the facility or maintaining some U.S. control to prevent uses detrimental to U.S. interests.

Following the COCOM member country agreement to a liberalization of controls on specific types of exports to China, the number of U.S.-China cases submitted to COCOM declined from 287 in January 1986 to 187 in April 1987. However, the approaches to export controls differ among the COCOM countries, and there is leeway for different interpretations of the China regulations within the discretion permitted COCOM members. **OTA's research indicated a need for further harmonization of COCOM country policies.**

OTA found widespread misunderstanding among businessmen in the United States and abroad about multilateral controls. There is a tendency for all to suspect their competitors of circumventing the rules, but **OTA found little hard evidence to support claims that foreign (COCOM) country governments are doing so.**

A major issue for the future will be whether to remove China exports from COCOM consideration. This would announce full acceptance of China as a Western trading partner, although the commercial implications for U.S. firms are uncertain. If China's current trends continue, this issue will be given serious consideration. However, COCOM members will be cautious because once review is ended, it would be awkward to reinstitute if China's policies later change.

Some exporters have complained that their dual-use technologies are subjected to more stringent controls and take longer to gain approval than military technologies. Sophisticated, state-of-the-art systems such as the F-8 avionics package embody some technology that will be useful to China even if sold as an end product, with no intentional technology transfer. Since the United States has made a policy decision to help China's military to this degree, dual-use exports should be judged by the same standards.

OTA finds that approvals of military and dual-use technology have not been inconsistent. The actual number of munitions cases reviewed has been much smaller than those reviewed for dual-use exports, and the rate of denial higher. Inconsistency could be a problem in the future unless the two sets of reviewers are more aware of what their counterparts are doing. Information about recent arms sales, for example, could be useful to those involved in review of related types of dual-use cases.

A number of factors suggest that U.S.-China military cooperation will continue to develop slowly. Taiwan is one of those factors. China continues to object to U.S. arms sales to Taiwan, while supporters of Taiwan carefully scrutinize the more limited U.S. sales to China. Continued differences over Taiwan may limit U.S.-China military cooperation in practice.

The United States has several promotional programs that support trade with and technology transfer to China, although these programs are not extensive nor coordinated into a comprehensive strategy as are those of Japan, for example. These protocols for science and technology cooperation help set the stage for expanding commercial interaction. The Foreign Commercial Service in the Department of Commerce provides information and assistance to U.S. businesses and helps potential buyers learn of U.S. goods and services. The Dalian Management Center, a training program for Chinese managers, is supported by DOC. The U.S. Government also tries to provide a favorable environment for trade and technology transfer through U.S. official discussions.

U.S. financing programs, including those of the Export-Import Bank, have been comparatively limited and have been guided by the general principle that the private sector should finance exports unless the project is of great national interest or unless a competing foreign bidder is assisted by a national government with subsidized loans. The Overseas Private Investment Corporation (OPIC) has insured more than 20 U.S. investments in China against political risk. Programs of both the Export-Import Bank and OPIC are, however, being scaled back in some areas because of budgetary constraints.

The Trade and Development Program (TDP) has been well received in China. TDP provides project planning services, including feasibility studies. These relatively modest investments can yield significant results. In 1982, for example, a $440,000 TDP feasibility study of a hydropower project led to $20 million in U.S. exports.

Since the United States has no formal aid program to China and because of opposition by some to the use of "mixed credits," which combine official credits and concessional financing, low-cost programs such as those of TDP provide an important tool for U.S. Government support at important early stages of projects.

China is a good test case for U.S. exports, and the U.S. Government could provide more support. U.S. exports to China were lower in 1986 than in 1980. Increases in exports of machinery and equipment were

more than offset by decreases in agricultural products. Congressional debates focus on whether the United States can maintain a policy directed at promoting free trade or whether protectionist responses will be forthcoming. Still another possibility would be to develop special bilateral understandings with China. U.S. policies affecting trade and technology transfer to China, however, must be part of an overall U.S. trade policy strategy to be effective over the long term. Technology transfer is a long-term relationship, and the participants could benefit from clear and consistent signals about the direction of government policies.

Specific actions on export control that Congress could consider include the following:

1. improve the efficiency of export control administration:
   - —require Operating Committee reports to Congress on greatly delayed cases;
   - —require more timely information on precedent setting export approvals;
   - —support automated systems to improve the efficiency of review; and
   - —set goals for faster licensing (e.g., 6 days for green-zone cases).
2. modify existing export control policy:
   - —give DOC authority to approve licenses unless *formally* appealed to the President, with automatic approval if cases back up for too long;
   - —require clearer guidelines for prohibited dual-use exports;
   - —require the development of plans for an enlarged green zone;
   - —improve information exchange between munitions and dual-use reviewers; and
   - —establish a distribution license procedure.
3. ensure that U.S. controls are in line with COCOM allies, even if that means dropping unilateral controls.

Potential congressional actions on trade promotion include the following:

1. expand existing programs, including TDP, the Foreign Commercial Service, and official financing;
2. modify existing policy to:
   - —encourage the development of sectoral trade strategies,
   - —review the science and technology protocols and revise government support as appropriate; and
3. initiate an official development assistance program for China.

Technology will continue to be a key element in the expanding U.S.-China relationship, yet one not easily manipulated by governments. Technology transfer can help create a constructive, long-term partnership, but it can also create new and, in some cases, unanticipated problems. Policies aimed narrowly at either the control or promotion of technology transfer to China without consideration of the larger context of U.S.-China relations and Asian security could prove counterproductive.

Related OTA Reports

- *Energy Technology Transfer to China—A Technical Memorandum*. OTA-TM-ISC-30, September 1985. GPO stock #052-003-01007-1; $4.50.
- *Technology Transfer to the Middle East*. OTA-ISC-173, September 1984. GPO stock #052-003-00962-5; $17.00. NTIS order #PB 85-127 744/AS.
- *Technology and East-West Trade: An Update*. OTA-ISC-209, May 1983. NTIS order #PB 83-234 955.
- *Technology and East-West Trade*. OTA-ISC-101, November 1979. NTIS order #PB 80-119 381.
- *Technology and Soviet Energy Availability*. OTA-ISC-153, November 1981. NTIS order #PB 82-133 456.

NOTE: Reports are available through the U.S. Government Printing Office, Superintendent of Documents, Washington, DC 20401-9325, (202) 783-3238; and the National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161, (703) 487-4650.

NOTE: Copies of the report "Technology Transfer to China" can be purchased from the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402, GPO stock No. 052-003-01069-1.

Assessments in Progress as of June 1987

Technology and the American Economic Transition
High-Technology Ceramics and Polymer Composites
Starpower: The U.S. and International Quest for Fusion Energy
Competitiveness of Domestic Copper
Technological Risks and Opportunities for Future U.S. Energy Supply and Demand
Increased Competition in the Electric Power Industry
Technology, Innovation, and U.S. Trade
Superfund Implementation
Seismic Verification of Nuclear Test Ban Treaties
Advanced Space Transportation Technologies
Defense Technology Base
Strategic Defense Initiative: Survivability and Software
Low-Resource Agriculture in Africa
African Development Foundation
Technology and Public Policy To Enhance Grain Quality in International Trade
Monitoring of Mandated Vietnam Veteran Studies
Technology and Child Health
Nontraditional Methods of Cancer Treatment: Science and Policy Issues
The Quality of Medical Care: Information for Consumers
Diagnostic Medical Tests: Impact on Public and Private Policies Toward Health Care
Drug Labeling in Developing Countries—Phase I
Federal Response to AIDS: Congressional Issues
Life-Sustaining Technologies and the Elderly
New Developments in Biotechnology
Infertility: Prevention and Treatment
Mapping the Human Genome
Methods for Locating and Arranging Health and Long-Term Care Services for Persons With Dementia
New Communications Technology: Implications for Privacy and Security
Technology, Public Policy, and the Changing Nature of Federal Information Dissemination
Communications Systems for an Information Age
Science, Technology, and the Constitution in the Information Age
Hospital Information Systems
From Gravel to Gold: Exploring Our Nations Ocean Frontier
New Clean Air Act Issues
Book Preservation Technologies
Sustaining the National Technological Base: Education and Employment of Scientists and Engineers
Educational Technology: An Assessment of Practice and Potential
Safety in the Commercial Aviation and Motor Carrier Industries

(NOTE: For brief descriptions of these studies in progress, see OTA booklet on "Assessment Activities"—available from OTA's Publications Office, 224-8996.)

General Information

Contacts Within OTA

OTA offices are located at 600 Pennsylvania Ave., S.E., Washington, DC.

Personnel Locator	224-8713
Publication Requests	224-8996
Office of the Director	224-3695
Congressional and Public Affairs Office	224-9241
Energy, Materials, and International Security Division	226-2253
Health and Life Sciences Division	226-2260
Science, Information, and Natural Resources Division	226-2253
Administrative Services	224-8712

Reports and Information

To obtain information on availability of published reports, studies, and summaries, call the OTA Publication Request Line (202) 224-8996.

Information on the operation of OTA or the nature and status of ongoing assessments, write or call:

Congressional and Public Affairs Office
Office of Technology Assessment
U.S. Congress
Washington, DC 20510-8025
(202) 224-9241

Other OTA Publications

List of Publications.—Catalogs by subject area all of OTA's published reports with instructions on how to order them.

Assessment Activities.—Contains brief descriptions of recent publications and assessments under way, with estimated dates of completion.

Press Releases.—Announces publication of reports, staff appointments, and other newsworthy activities.

OTA Annual Report.—Details OTA's activities and summarizes reports published during the preceding year.

OTA Brochure.—"What OTA Is, What OTA Does, How OTA Works."

CONGRESS OF THE UNITED STATES
OFFICE OF TECHNOLOGY ASSESSMENT
WASHINGTON, D.C. 20510-8025

OFFICIAL BUSINESS
PENALTY FOR PRIVATE USE $300

POSTAGE AND FEES PAID
OFFICE OF TECHNOLOGY ASSESSMENT
379

U.S.MAIL

OTA-ISC-341

JUNE 1987